

What is claimed is:

- 1 1. A Bernoulli end effector comprising:
2 a support member defining at least one passage for directing a fluid at a substrate to
3 apply a holding force and a drag force on the substrate;
4 at least one edge guide in mechanical communication with the support member for
5 contacting an edge of the substrate to oppose the drag force applied by the fluid; and
6 at least one friction pad in mechanical communication with the support member for
7 contacting a surface of the substrate to impede a rotational motion of the substrate.
- 1 2. The Bernoulli end effector of claim 1, wherein the at least one friction pad is attached
2 to the at least one edge guide.
- 1 3. The Bernoulli end effector of claim 1, wherein the at least one passage comprises a
2 first plurality of passages symmetrically arranged about an axis of the support member and a
3 second plurality of passages asymmetrically arranged about the axis of the support member.
- 1 4. The Bernoulli end effector of claim 3, wherein the first plurality of passages are
2 arranged in a circular pattern for providing a Bernoulli force perpendicular to a surface of the
3 substrate.
- 1 5. The Bernoulli end effector of claim 3, wherein the second plurality of passages are
2 arranged in an arc for providing the drag force on the substrate.
- 1 6. The Bernoulli end effector of claim 1, wherein an angle between a direction defined
2 by the at least one passage and a surface of the support member is at least approximately
3 thirty degrees.
- 1 7. The Bernoulli end effector of claim 1, wherein the at least one friction pad is disposed
2 for contacting the substrate within 2 mm of an edge of the substrate.

1 8. The Bernoulli end effector of claim 1, wherein the at least one friction pad comprises
2 an elastomer.

1 9. The Bernoulli end effector of claim 1, wherein the at least one friction pad comprises
2 alumina.

1 10. The Bernoulli end effector of claim 1, wherein the at least one edge guide is beveled.

1 11. The Bernoulli end effector of claim 1, wherein the hold force is first applied and the
2 drag force is applied after a delay of between about 100 ms and 250 ms.

1 12. A method for handling a substrate with a Bernoulli end effector, the method
2 comprising:
3 directing a fluid at the substrate to apply a holding force and a drag force to the
4 substrate, the holding force creating a low pressure Bernoulli force to lift the substrate;
5 applying a counter force to an edge of the substrate to oppose the drag force; and
6 applying a frictional force to a surface of the substrate adjacent to the edge of the
7 substrate to impede a rotational motion of the substrate.

1 13. The method of claim 12, wherein the hold force is first applied and the drag force is
2 applied after a delay.

1 14. The method of claim 13, wherein the delay is between about 100 ms and 250 ms.

1 15. A method for handling a substrate with a Bernoulli end effector, the method
2 comprising:
3 directing a fluid at the substrate to apply a holding force to the substrate, the holding
4 force creating a low pressure Bernoulli force to lift the substrate;
5 applying a drag force after applying the holding force; and
6 applying a counter force to an edge of the substrate to oppose the drag force.

1 16. The method of claim 15, wherein the drag force is applied between about 100 ms and
2 250 ms after the holding force is applied.

1 17. The method of claim 15, further comprising applying a frictional force to a surface of
2 the substrate adjacent to the edge of the substrate to impede a rotational motion of the
3 substrate.

1 18. A substrate handling structure comprising:
2 a substrate carrier comprising a substrate support feature;
3 a substrate clamp moveable between a lowered position for securing a substrate on
4 the substrate support feature and a raised position to permit placing the substrate on the
5 substrate support feature; and
6 at least one guide disposed adjacent to the substrate support feature for impeding a
7 lateral movement of the substrate when the substrate clamp is in the raised position.

1 19. The substrate handling structure of claim 18, wherein the at least one guide is
2 retractably mounted for retracting the at least one guide when the substrate clamp secures
3 the substrate.

1 20. The substrate handling structure of claim 19, wherein the substrate clamp is
2 configured to cause the at least one guide to retract when the substrate clamp is moved from
3 the raised position to the lowered position.

1 21. The substrate handling structure of claim 18, wherein the substrate clamp is
2 configured to cover only a surface portion adjacent to an edge of the substrate.

1 22. The substrate handling structure of claim 19, wherein the at least one guide comprises
2 a spring that urges the guide to project above a surface of the substrate carrier.

1 23. The substrate handling structure of claim 18, wherein the at least one guide is
2 attached to the substrate carrier.

- 1 24. The substrate handling structure of claim 19, wherein the substrate carrier defines at
2 least one cavity within which the at least one guide is moveably mounted.
- 1 25. The substrate handling structure of claim 18, wherein the at least one guide comprises
2 a first portion and a second portion that is flexibly attached to the first portion, the second
3 portion for contacting the substrate.
- 1 26. The substrate handling structure of claim 21, wherein the substrate clamp comprises a
2 beveled edge portion configured to contact the substrate and gently center the substrate on
3 the substrate support feature.
- 1 27. An apparatus for supinating a substrate, the apparatus comprising:
2 a first substrate chuck for securing the substrate while a first surface of the substrate
3 is exposed;
4 a second substrate chuck spaced in opposition to the first substrate chuck for securing
5 the substrate after receiving the substrate from the first substrate chuck to expose a second
6 surface of the substrate; and
7 an end effector for at least one of delivering the substrate to the first substrate chuck
8 and receiving the substrate from the second substrate chuck.
- 1 28. The apparatus of claim 27, wherein the end effector is rotatably mounted for rotating
2 the substrate about an axis parallel to a face of the substrate.
- 1 29. The apparatus of claim 27, wherein the first chuck and the second chuck are each
2 fixedly mounted.
- 1 30. The apparatus of claim 27, wherein the first chuck and the second chuck are mounted
2 in a fixed relationship to each other, and together are rotatably mounted for rotating a
3 substrate secured by one of the first and second chucks.

1 31. The apparatus of claim 27 wherein at least one of the first and second chucks is a
2 Bernoulli chuck.

1 32. The apparatus of claim 27 wherein at least one of the first and second chucks is an
2 electrostatic chuck.

1 33. The apparatus of claim 27, wherein the end effector is a Bernoulli end effector.

1 34. The apparatus of claim 33, wherein the Bernoulli end effector comprises at least one
2 friction pad in mechanical communication with a support member for contacting a surface of
3 the substrate adjacent to an edge of the substrate to impede a rotational motion of the
4 substrate.

1 35. The apparatus of claim 34, wherein the Bernoulli end effector further comprises at
2 least one edge guide.

1 36. The apparatus of claim 33, wherein the Bernoulli end effector comprises a first
2 plurality of passages symmetrically arranged about an axis of the support member and a
3 second plurality of passages asymmetrically arranged about the axis of the support member.

1 37. The apparatus of claim 34, wherein the at least one friction pad is disposed for
2 contacting the surface of the substrate adjacent to an edge of the substrate within
3 approximately 2 mm of the edge of the substrate.

1 38. The apparatus of claim 27, further comprising an actuator in mechanical
2 communication with the first substrate chuck, the actuator controlling the spacing between
3 the first substrate chuck and the second substrate chuck.

1 39. The apparatus of claim 27, further comprising a sensor for monitoring the position of
2 the substrate.

1 40. The apparatus of claim 39, wherein the sensor is a camera.

1 41. The apparatus of claim 39, wherein the sensor is integrated with at least one of the
2 first substrate chuck and the second substrate chuck.

1 42. A method for supinating a substrate, the method comprising:
2 securing a substrate with a first substrate chuck such that a first surface of the
3 substrate faces the first substrate chuck;
4 transferring the substrate to a second substrate chuck that is spaced in opposition to
5 the first substrate chuck such that a second surface of the substrate faces the second substrate
6 chuck; and
7 receiving the substrate from the second substrate chuck to expose the second surface
8 of the substrate.

1 43. The method of claim 42, further comprising transferring, by an end effector, the
2 substrate to the first substrate chuck.

1 44. The method of claim 43, wherein the end effector is a Bernoulli end effector.

1 45. The method of claim 43, wherein receiving the substrate from the second substrate
2 chuck comprises receiving, by the end effector, the substrate.

1 46. The method of claim 45, further comprising rotating a portion of the end effector after
2 transferring the substrate to the first substrate chuck and before receiving the substrate by the
3 end effector.

1 47. The method of claim 43, further comprising applying a frictional force to a surface of
2 the substrate that is adjacent to an edge of the substrate to impede a rotational motion of the
3 substrate when the substrate is held by the end effector

1 48. The method of claim 44, wherein the Bernoulli end effector comprises a first plurality
2 of passages symmetrically arranged about an axis of the support member and a second
3 plurality of passages asymmetrically arranged about the axis of the support member.

1 49. The method of claim 42, further comprising translating at least one of the first
2 substrate chuck and the second substrate chuck to control the spacing between the first
3 substrate chuck and the second substrate chuck prior to transferring the substrate.

1 50. The method of claim 42, further comprising sensing the position of the substrate.

1 51. A Bernoulli end effector comprising:
2 means for directing a fluid at a substrate to applying a holding force and a drag force
3 to the substrate, the holding force creating a low pressure Bernoulli force to lift the substrate;
4 means for applying a counter force to an edge of the substrate to oppose the drag
5 force; and
6 means for applying a frictional force to a surface of the substrate adjacent to the edge
7 of the substrate to impede a rotational motion of the substrate.

1 52. The Bernoulli end effector of claim 51, further comprising means for first applying
2 the hold force and then applying the drag force..

1 53. An apparatus for supinating a substrate, the apparatus comprising:
2 means for securing a substrate with a first substrate chuck such that a first surface of
3 the substrate faces the first substrate chuck;
4 means for transferring the substrate to a second substrate chuck that is spaced in
5 opposition to the first substrate chuck such that a second surface of the substrate faces the
6 second substrate chuck; and
7 means for receiving the substrate from the second substrate chuck to expose the
8 second surface of the substrate.

1 54. The apparatus of claim 49, further comprising means for transferring, by an end
2 effector, the substrate to the first substrate chuck.

1 55. The apparatus of claim 53, further comprising means for rotating the means for
2 receiving the substrate.

1 56. The apparatus of claim 53, further comprising means for applying a frictional force to
2 a surface of the substrate.

1 57. The apparatus of claim 53, further comprising means for translating at least one of the
2 first substrate chuck and the second substrate chuck to control the spacing between the first
3 substrate chuck and the second substrate chuck.

1 58. The apparatus of claim 53, further comprising means for sensing a position of the
2 substrate secured by the first substrate chuck..